$\beta_0 = 6.1 \times 10^{-13}$ (dyne/cm^2)$^{-1}$. However, it should be noted that the scatter of points in Bridgman's compressibility measurements (*2*) is approximately 3 times that of ours and that Bridgman did not detect a break in the compressibility curve. A plot of $\Delta V/V$ against P at 30°C as given by Bridgman (*1*) (he gave smoothed data at 1-kb intervals) indicates that the initial compressibility was probably considerably higher than 5×10^{-13} which is the slope of his line between 1 and 12 kb.

In an extended x-ray run in which the diffraction pattern was scanned every 5 kb, we found that Cr remains in a body-centered cubic crystal structure from 0 to 55 kb at 28°C.

WILLIAM E. EVENSON
H. TRACY HALL
Department of Physics and Chemistry, Brigham Young University, Provo, Utah

References and Notes

1. P. W. Bridgman, *Proc. Am. Acad. Arts Sci.* **68**, 27 (1933).
2. ———, *ibid.* **62**, 207 (1927).
3. T. Mitsui and C. T. Tomizuka, *Phys. Rev.* **137**, A564 (1965).
4. D. T. Litvin and E. G. Ponyatovskii, *Dokl. Akad. Nauk. SSSR* **156**, 69 (1964); English trans., *Soviet Phys.-Dokl.* **9**, 388 (1964).
5. F. F. Voronov, *J. Exp. Theoret. Phys. USSR* **47**, 1999 (1964); English trans., *Soviet Phys.-JETP* **20**, 1342 (1965).
6. J. D. Barnett and H. T. Hall, *Rev. Sci. Instr.* **35**, 175 (1964).
7. R. N. Jeffrey, J. D. Barnett, H. Vanfleet, H. T. Hall, in preparation.
8. Supported by the Army Research Office (Durham) and NSF.

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Sea-Level Changes during the Last 2000 Years at Point Barrow, Alaska

Abstract. *Eustatic rises of sea level between A.D. 265 and 500 and between A.D. 1000 and 1100 caused the formation of raised beaches. After the first rise, sea level dropped about 2 meters below the present level, permitting Eskimo settlement of Birnirk about A.D. 500. The second rise of the ocean flooded Birnirk. At present, sea level is about 0.6 to 1.0 meter below the high-water levels; the ocean partially floods Birnirk.*

During the summer of 1964 a fossil log was found in place in old beach ridges on Point Barrow, Alaska. Digging produced two more pieces of driftwood. These specimens were buried in an area where datable material had not been found and where the sediments were among the oldest on Point Barrow. The samples were dated by radiocarbon methods in an attempt to add to the geologic history of the region. In particular, evidence for changes of sea level and their effect on early Eskimo settlements was desired. The dates should be of interest to scientists of several disciplines because the area has been used for studies in geology, anthropology, biology, limnology, and climatology. These studies are still in progress, and a major attempt is being made to unravel the Pleistocene and Recent history (*1*).

Point Barrow (Fig. 1) is the northernmost point in the United States. It was part of a spit until 3 October 1963, when a major storm breached the spit just northeast of its junction with the mainland. Because these breaks are expected to heal within a few years, the Point Barrow area is still referred to as the Barrow spit. The spit extends northeast from the mainland for a distance of 8 km to Point Barrow. There the spit hooks and curves southeastward for 5 km. In most areas, patterns of beach ridges occur. The sediment forming these ridges has been described by Rex (*2*) and by Péwé and Church (*3*). It is chiefly chert of sand and gravel sizes.

The beach ridges can be grouped into three series (Fig. 1) first recognized by Rex (*2*). The youngest series is actively growing and is on the west; the oldest is on the east. The older two series contain beaches higher than those in the youngest series. Elevations over 4 m above sea level are found along the ridges passing through reference mark No. 2 of the Nuwuk bench mark and Hole No. 4, drilled by Péwé and Church (Fig. 1). The beach ridges in the youngest series reach elevations of 3.5 m but are mostly about 2 m above sea level. In general, within the older two series, the higher beach ridges are on the west. Ice wedges can be found in the older sets of ridges; soil a few centimeters thick has developed on the oldest beaches.

The highest ridges of both older series of beaches are thought to have been formed when sea level was about 0.6 to 1.0 m higher than it is now, for they are about 0.6 to 1.0 m higher than the highest of the younger ridges and the same distance higher than the highest beach ridge built by the storm of 1963. Water from that storm did not wash over the highest older ridges. The storm was stronger and produced a higher sea level than any previously mentioned in Eskimo tales or recorded by others; by conservative estimate, it was the worst storm in 100 years. Its severity was the result of record high winds and an unusually ice-free ocean. Therefore, while there is some possibility that a past storm built beach ridges over 4 m above sea level without a rise in sea level, it seems that a higher sea level is the more likely possibility. Moore also ascribed elevated beach ridges near Point Hope and Cape Kruzenstern to higher stands of sea level (*4*).

The lower beach ridges in the older series may represent either low stands of the sea or ridges which were formed during average storms of the past. The old Eskimo site of Birnirk (Fig. 1), located on beach ridges forming the base of the Barrow spit, is at present partially drowned (*5*). During the occupation of this settlement, the sea must have been lower than it is now. Comparison with a nearby present-day Eskimo settlement suggests that the sea must have been about 2 m below its present level during the occupation of Birnirk. Moore (*4*) also thought that low stands of the sea were demonstrated at Point Hope.

The three pieces of driftwood found in 1964 in the eroded bluffs at Nuwuk were in beach deposits having an average dip of about 3° northwest. The stratigraphic position of each of the samples corresponded with the following ages (*6*): sample GX0380, 1700 ± 110 years ago; sample GX0381, 2365 ± 100 years; sample GX0230, 5575 ± 375 years.

The positions of the specimens were all related to the second reference mark of the Nuwuk bench mark (Fig. 1). The elevation of the top of the marker was taken as 4.2 m above mean low water. The oldest specimen (GX0230) was 22 m north 57° east of the reference mark and 2 m above mean low water. The specimen was a badly weathered log at least 2 m long and about 20 cm in diameter. The log had been split and the bottom was missing. The middle sample (GX0381) was 2.5 cm in diameter and 15 cm long. It was 22 m north 6½° west of the reference mark at an elevation of 1.4 m. Nearby was the youngest piece of wood (GX0380), 3.1 cm in diameter and 21.5 cm long. It was 21 m north 5½° west of the reference mark and 1.7 m above sea level.

All three specimens were found in the same beach ridge (Fig. 1). There was no evidence of a major stratigraphic break in the sediments containing the fossil wood. Hence the entire

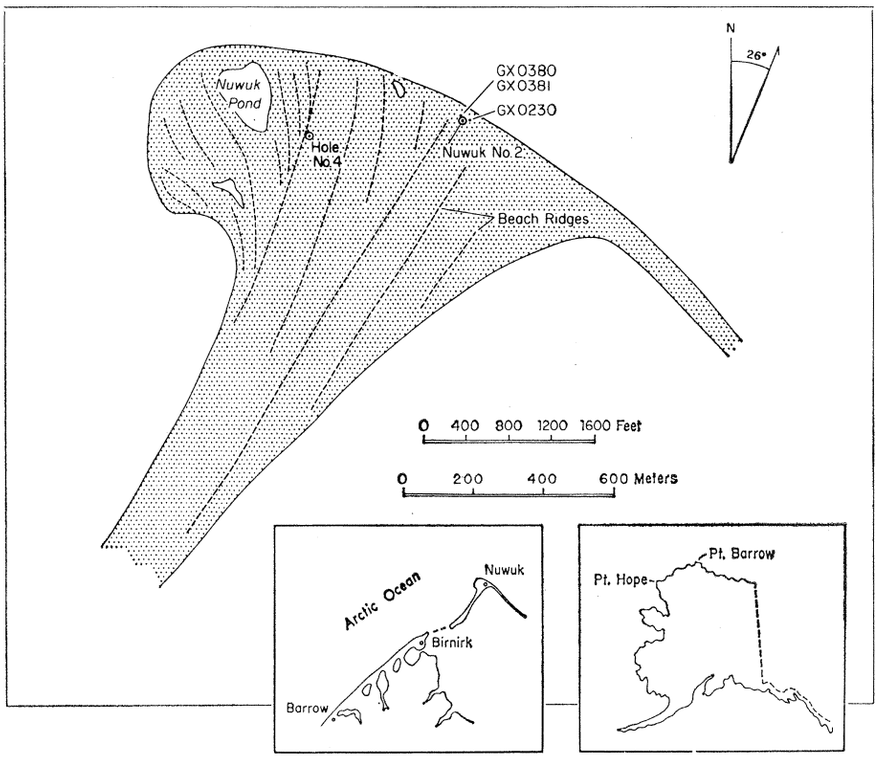

Fig 1. Point Barrow, Alaska. Detailed map modified from aerial photograph taken in June 1960.

beach ridge is considered to be of approximately the same age and younger than the youngest sample. Because the beach ridge was one of the high beach ridges, there must have been a rise in sea level of approximately 0.6 to 1.0 m when the ridge was formed after A.D. 265. The older wood fragments have probably been recycled. The oldest may have been originally deposited in the Gubic formation.

After the high beach ridge was formed, sea level decreased, leaving the Birnirk area enough above sea level for human settlement. No absolute dates are available for the site itself, but a few dates are available for the Birnirk culture. Rainey and Ralph (*7*) have dated some Birnirk artifacts. Their samples P-73 and P-97 come from the Kugusugaruk excavations 18.5 kilometers southwest of Barrow (*1*) and are considered by Ford (*5*) to be early Birnirk in age. Sample P-73, probably a wooden handle, had an average age of 1445 ± 190 years with two parts of the same sample giving dates 300 years apart. Sample P-97, a wooden meat tray, was 1160 ± 95 years old. Two other artifacts were 1335 ± 230 (P-65) and 1495 ± 240 years old (P-63). While more dates are needed, it appears that the Birnirk culture must have been in existence about A.D. 500. Birnirk was also probably settled about then, and a sea about 2 m lower than at present must have existed to bring the area sufficiently above sea level for human occupation. Therefore, sea level must have dropped about 3.0 m between A.D. 265 and 500, after the earlier period of high sea level when the first high beach ridges were built.

In 1961, when drilling ice wedges, Péwé and Church (*3*) found three pieces of driftwood in their Hole No. 4. Specimen 1 was 1115 ± 120 years old, specimen 2 was 1105 ± 140 years old, and specimen 3 was 10,800 ± 300 years old. Specimen 3 was the lowermost and was thought to have been reworked. Specimens 1 and 2 provided reasonable dates for the beach ridge in which they were found. The dates are in accord with an age based on rate of sedimentation. Therefore, the beach ridge may have been formed as early as A.D. 860. The sediments were found in one of the high beach ridges; hence sea level must have risen approximately 0.6 to 1.0 m above the present level after that time. This represents a 3.0-m rise of sea level from that necessary for the occupation of Birnirk.

Moore (*4*) thought that the Point Hope region demonstrated a low sea level from A.D. 900 to 1000, a high stand from 1000 to 1100, and another low stand from 1700 to 1850. If this is true, the last high beach at Barrow was probably built about 1000–1100, and the youngest wood specimen found in it was in transit or temporarily deposited for about 150 years. During this period when the north and northwest coasts of Alaska were slightly submerged, the Birnirk site must have been flooded and its occupants driven to new homes, where the culture persisted until about A.D. 1250 (*5*).

Since then, sea level at Barrow has dropped about 0.6 to 1.0 m to its present position. The Birnirk site is still partially flooded (*5*). Other fluctuations of sea level may have occurred, but they have not been detected near Barrow. Moore (*4*) has found them at Point Hope and it is hoped that the investigations of Brown (*1*) will provide further information.

The sea level changes are considered to be eustatic for several reasons. Lachenbruch (*8*) thought the Barrow area had been tectonically stable during the last few thousand years. The region is not subject to earthquakes, and it was not glaciated. Finally, there seems to be some correlation between sea level changes at Point Hope and Point Barrow.

The evidence presented here supports Fairbridge's (*9*) suggestion that sea level has fluctuated slightly above and below the present level during the last few thousand years. The absolute dates do not correlate well with his dates. The low stand of the sea during the period A.D. 500–1000 approximates the sea level shown by Shepard (*10*). The high stands, however, would have to be considered as fluctuations superimposed on his more generalized curve for changes in sea level.

JAMES D. HUME
Department of Geology, Tufts University, Medford, Massachusetts

References and Notes

1. J. Brown, *Arctic* **18**, 36 (1965).
2. R. W. Rex, *Papers in Marine Geology* (Macmillan, New York, 1964), pp. 384–391.
3. T. L. Péwé and R. E. Church, *Bull. Geol. Soc. Amer.* **73**, 1287 (1962).
4. G. W. Moore, *U.S. Geol. Survey Profess. Paper 400-B* (1960), p. B335.
5. J. A. Ford, *Amer. Mus. Nat. His. Anthropol. Paper 47* (1959), p. 1.
6. Radiocarbon ages are given in years before 1965. Dating was done by Geochron Laboratories, Inc.
7. F. Rainey and E. K. Ralph, *Amer. Antiquity* **24**, 365 (1959).
8. A. H. Lachenbruch, *Bull. Geol. Soc. Amer.* **68**, 1515 (1957).
9. R. W. Fairbridge, *Phys. Chem. Earth* **4**, 99 (1961).
10. F. P. Shepard, *Science* **143**, 574 (1964).
11. Work supported by the Arctic Institute of North America under contractual arrangements with the ONR. Field support provided by the Arctic Research Laboratory. I thank Patricia W. Hume, Derwin Bell, Donald B. Biederman, David McCulloch, and Louis I. Briggs for their help.

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